Informal Update on Preliminary Engineering Design Study for SNAP Optical Telescope Assembly

September 30, 2002

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Summary

After visiting COI and receiving feedback on the draft report of August 9, 2002, further studies of the Optical Telescope Assembly (OTA) have been undertaken. Numerous variations and iterations were modeled, and a model with a total weight of around 1900 pounds and a fundamental frequency of 60 Hz is described in this Update. In addition, some explanation of the effects on natural frequency of certain variations in the design is provided here.

Reasons for the evolution of the model include:

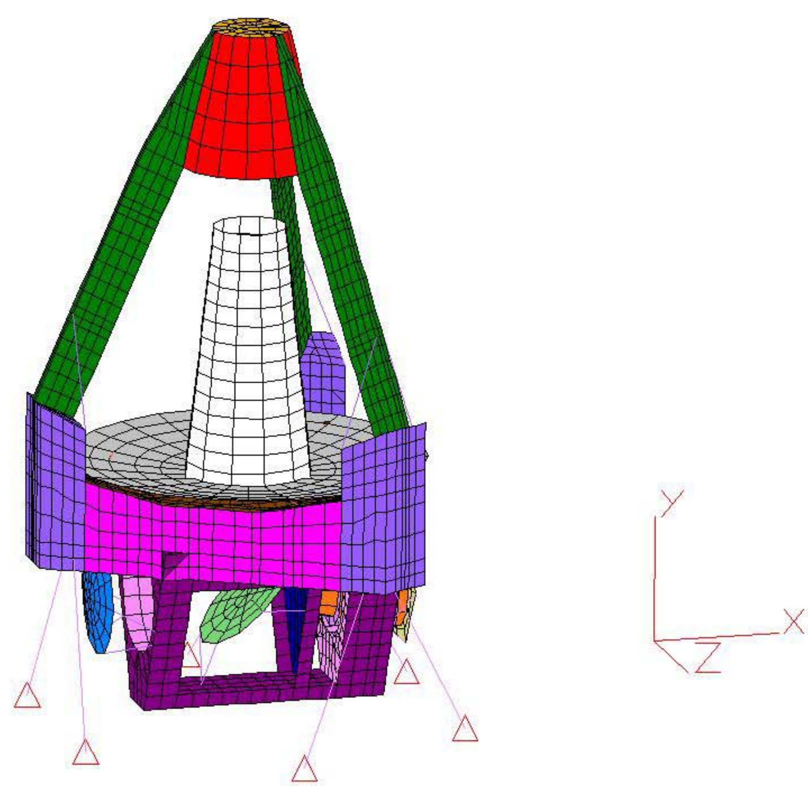
-The indication from COI that carbon fiber/cyanate ester (cfce) layups for stable optical platforms should be 2mm thick or less, primarily because of shrinkage from moisture loss. Specifically, my understanding is that for the anticipated layup (M55J fibers in a quasi-isotripic layup), shrinkage due to moisture loss amounts to 130 ppm per percent moisture loss, and expected initial moisture content is 0.4%. Dryout time after launch for 2mm material at 300K is on the order of a few months. [Note that COI literature from the web indicates Total Mass Loss of 0.31% for CE3 Cyanate Ester alone, and 0.15% for ~60%-fiber-volume carbon fiber laminates. Two CE systems from Bryte Technologies have data on the web indicating TML for CE alone of 0.36% and 0.18%. The specific gravity of CE is around 1.2. That 0.4% number looks conservative.]

-The sense that the angular 'bell bottoms', which were used to stiffen the bases of the Secondary Mirror Assembly (SMA) support legs, might be difficult to produce/assemble and would likely have undesirable or unpredictable overall effects on thermal stability.

-COI's statements that the elastic modulus used in the previous study (20 Mpsi) is too high, and a better value is 14 Mpsi.

Description of the model

The current model (obmodel61) is illustrated in the following 4 figures. The second and third figures show interior details of the bench and the instrument bay (coffin). The fourth figure shows the eggcrating pattern in plan view. Some details of the FEA model are listed in the table that follows.



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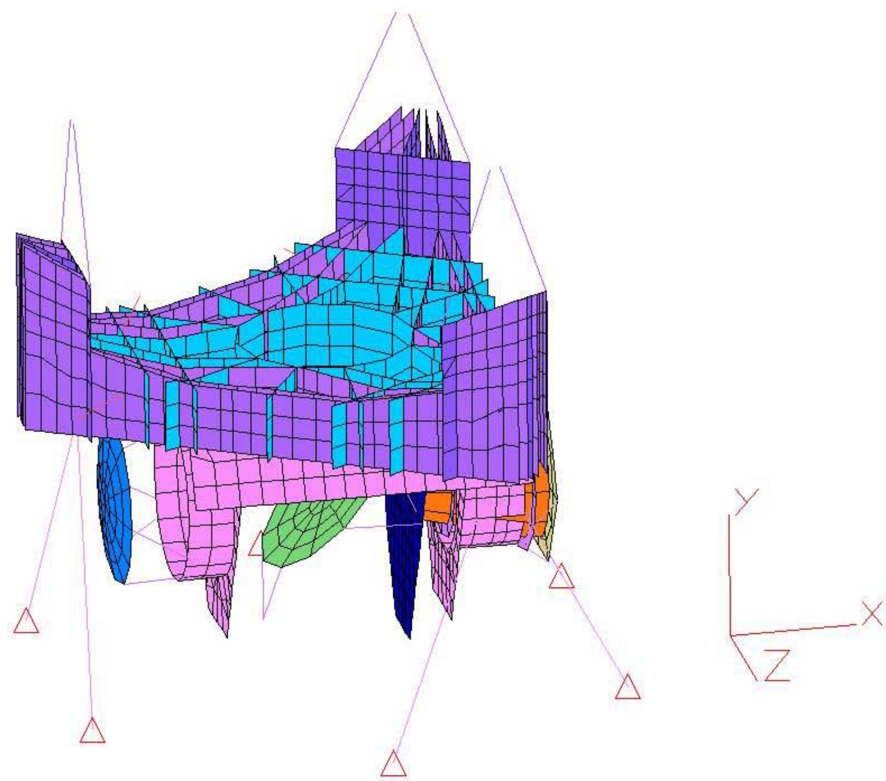

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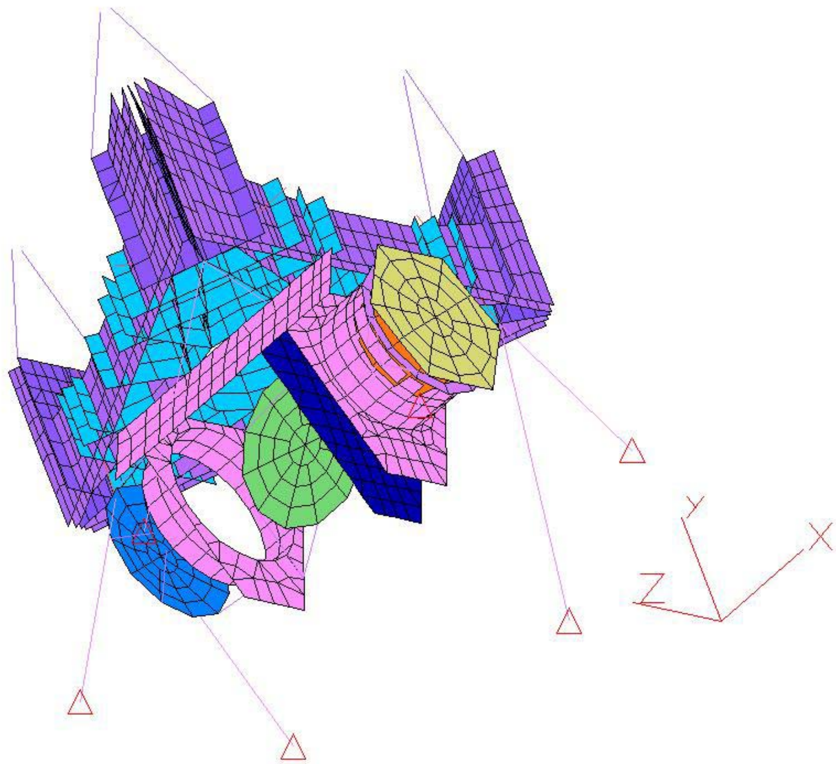
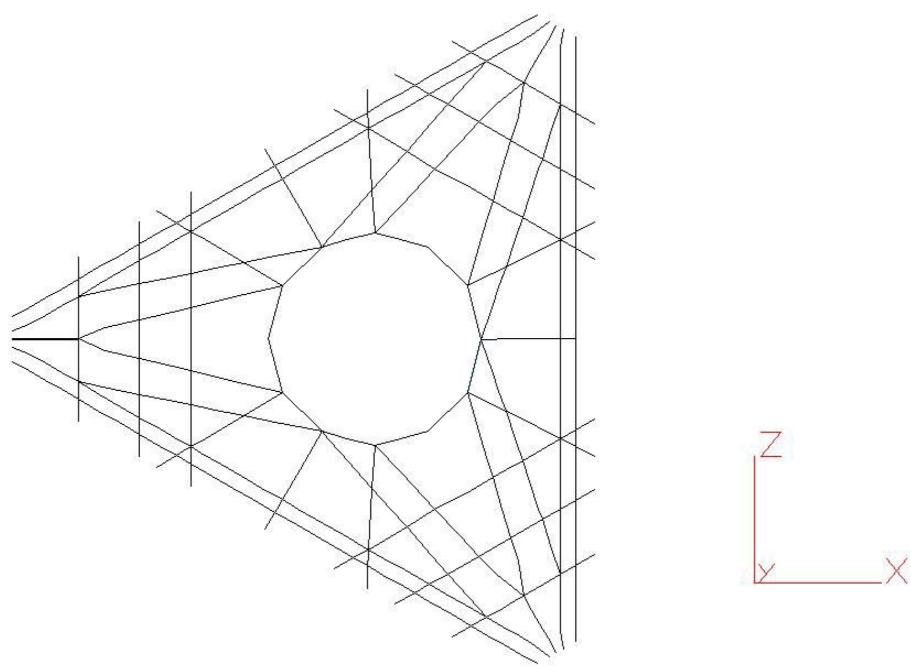


SVIEW 12.0 obmodel61 07/22/102 16:52 LC 1/ 10 Vu=U1 Lo= 47 La= 44 R= 78



SVIEW 12.0 obmodel62 07/22/102 16:52 LC 1/ 10 Vu= 2 Lo= 0 La= 0 R= 0

Total number of nodes=5056

layer, group	item	# of ele-ments	truss x-sec area (in^2)	plate thk (in)	wt dens (lb/in^3)	mass dens (lb-s^2/in^4)	E (Msi)	nu	description
1	SMA support legs	882		0.08	0.0696	0.000180	14	0.278	grep
2	SMA bucket	110		0.125	0.0696	0.000180	200	0.32	density of grep, extreme stiffness
3	SMA mass discs	106		0.2	0.3516	0.000910	200	0.32	density of grep + 35 lb, extreme stiffness
4	bench eggcrating	564		0.08	0.0696	0.000180	14	0.278	grep
5	bench face sheets	1040		0.08	0.0696	0.000180	14	0.278	grep
6	bench side sheets, skirts	252		0.08	0.0696	0.000180	14	0.278	grep
7	central baffle (stovepipe)	252		0.05	0.0696	0.000180	14	0.278	grep
8	primary mirror	120		9.6	0.0240	0.000062	2.94	0.17	70% lightweighted ule glass
9	instrument bay	579		0.08	0.0696	0.000180	14	0.278	grep
10	shutter assy	92		0.472	0.0978	0.000253	20	0.33	aluminum density, double aluminum stiffness
11	tertiary mirror	42		3	0.0240	0.000062	2.94	0.17	70% lightweighted ule glass
12	folding mirror	42		2.76	0.0240	0.000062	2.94	0.17	70% lightweighted ule glass
13	instrument	42		1.043	0.0978	0.000253	30	0.33	aluminum density, triple aluminum stiffness
14	cosmic ray shield	48		0.25	0.2230	0.000577	10	0.33	elastic props of al, density for 30kg
15	primary mirror struts	6	1		0.0696	0.000180	14	0.278	grep trusses
16	instrument bay stiffeners	348		0.08	0.0696	0.000180	14	0.278	grep
17	OTA support struts	6	12		0.0696	0.000180	14	0.278	grep trusses
18	cosmic ray shield struts	9	0.02		0.1598	0.000414	16.5	0.34	Ti trusses
19	instrument struts	6	0.1		0.1598	0.000414	16.5	0.34	Ti trusses
20	cosmic ray shield stiffeners	24		0.25	0.0978	0.000253	10	0.33	aluminum
21	folding mirror struts	6	0.2		0.0696	0.000180	14	0.278	grep trusses
22	tertiary mirror support	6	0.2		0.0696	0.000180	14	0.278	grep trusses
23	add'l bench eggcrating	528		0.08	0.0696	0.000180	14	0.278	grep
24	add'l bench eggcrating	378		0.08	0.0696	0.000180	14	0.278	grep
25	SMA leg support strut	6	1		0.0696	0.000180	14	0.278	grep trusses
26	bench corner towers	594		0.08	0.0696	0.000180	14	0.278	grep
27	inner faces of bench corner towers	210		0.16	0.0696	0.000180	14	0.278	grep
28	single vertical ribs in towers	84		0.08	0.0696	0.000180	14	0.278	grep
	total	6382							

The instrument, mirrors, Secondary Mirror Assembly, shutter assembly, cosmic ray shield, central baffle (stovepipe), and the supports for the OTA, mirrors, cosmic ray shield, and instrument are essentially as described in the August 9 Report. Note that the Sagem/Reosc analysis of the primary mirror and my concurrent analysis are ongoing, and the support scheme in those studies differs fundamentally from that presented here. Further development should see a convergence on a likely design.

The structure is composed almost entirely struts of varying materials and 0.080" thick cfce. The inward-facing surfaces of the three towers at the corners (model layer 27) are composed of 0.16" thick cfce. These surfaces extend all the way down to the bottom face sheet of the bench. The struts supporting the SMA legs, the primary mirror struts, and the OTA support struts all attach to these 0.16" sheets, and the added stiffness of the sheets contribute to the stiffness of the entire system. These sheets could conceivably be composed of cfce/honeycomb constructions, so dryout time would be that of 0.080" cfce. They could alternately be stiffened with intrinsic ribs or carbon fiber or invar struts.

The optic bench differs from that of the previous report in the following ways:
-The lengths of its corner sides are increased from around two inches to around twelve inches.
-There is now a 6" deep skirt extension around its periphery.
-The insides of the bench are eggcrated with crisscrossing vertical sheets of cfce.
-Towers are constructed at the corners of the bench to provide a stiff mounting for the SMA support, approximately 1 ½" above the actual front edge of the primary mirror. The eggcrating continues into and up these towers.
-The top face now ramps up toward the corners to provide greater stiffness while still remaining clear of the back of the primary mirror.

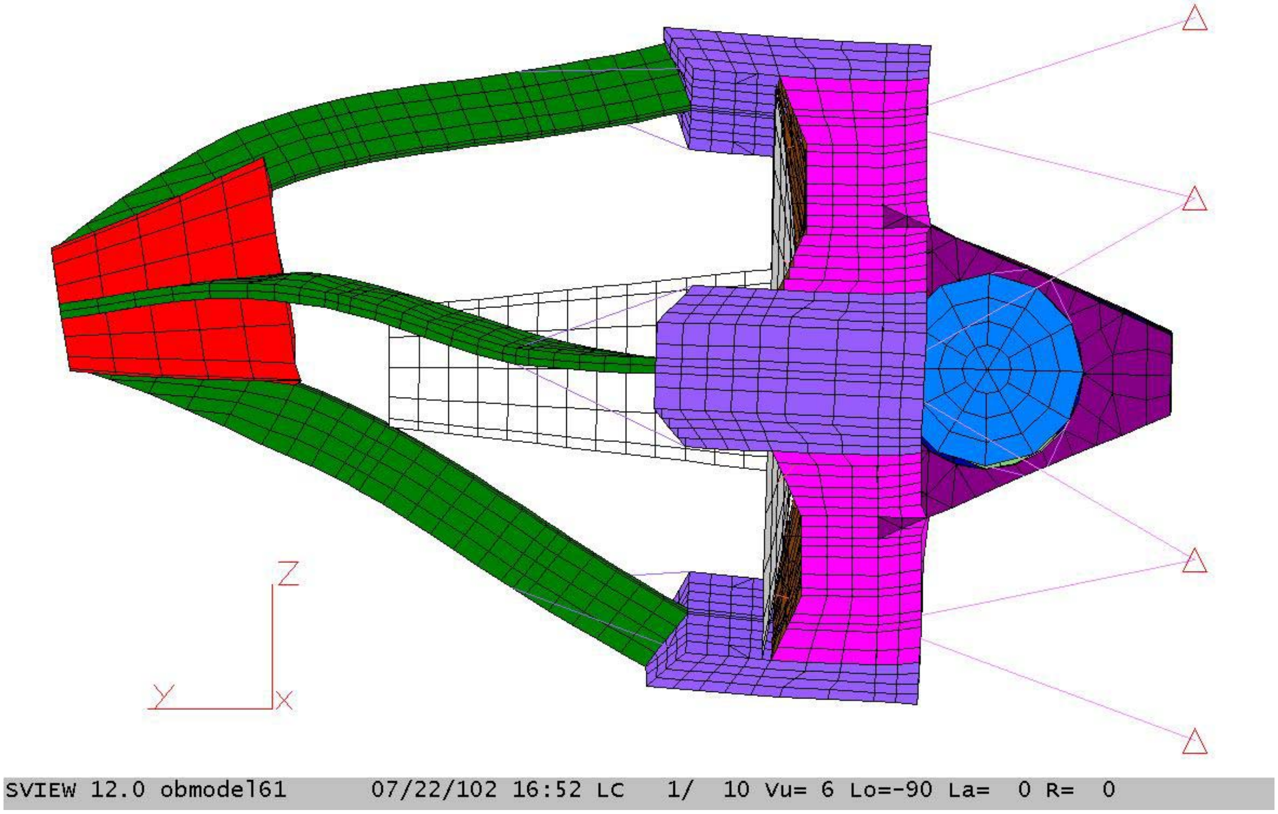
The SMA support legs are now 2 ¼" wide at their widest, tapering at a 1 ½ degree included angle in the direction of the optical axis to 1 ½" at their narrowest. They are 10" deep, and contain 4 internal bulkheads to eliminate low-frequency drumhead-like oscillations of the long faces of the legs. Each of the legs is stiffened by two cfce struts, each one square inch in cross section, reaching as high on the leg as possible without entering the field of view of the telescope.

The flat ends of the instrument bay (coffin) now are comprised of two sheets of 0.080" thick cfce, attached at their outsides to the triangular coffin and at their insides to cylindrical cfce sheets (these features are visible in pink in the exposed figures). The instrument end of the coffin has been extended so that it is still coplanar with the edge of the optics bench (which moved because the bench corners grew).

Analysis results

Stress analyses have not yet been performed on this model. Previous results indicate that natural frequency requirements help ensure high safety factors against material failure under quasi-static loading. Deflections of optical components in one-g testing configurations have not yet been evaluated, and optics mounting details are likely to change significantly from those in this model.

The following figure shows the first mode, with a frequency of 60.8 Hz.



The approximate effects on fundamental frequency of several design variations are described below. Note that these values are rough because they have been implemented at different stages in the evolution of the design, so they may not have the same effect on the current design.

-Employing a flat-topped optics bench, rather than one sloped up in the corners lowers natural frequency by around 3 ½ Hz.
-Growing the length of the corner sides was worth perhaps 4 Hz.
-A single eggcrating rib (per side of the bench) that runs from corner to corner is worth around 1 Hz.
-The presence of the optics bench skirt is worth ½-1 Hz.
-Reducing the weight of the entire SMA (mass discs and ‘flower pot’) by 25% (from ~64# to ~48#) increases natural frequency about 1 Hz.
-Making the inner sheets on the optics bench towers 0.08” thick instead of 0.16” thick reduces natural frequency by about 1 Hz.